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DISCUSSION OF CONSTRUCTION TECHNIQUE OF PASSING FLOODS OVER EARTH DAMS

(Published in October, 1950)

By Cleves H. Howell, Gerard H. Matthes, and Andrew Weiss

IRRIGATION DIVISION

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Technical Division	*Proceedings-Separate Number*
Air Transport	42, 43, 48, 52, 60 (Discussion: D-XXVIII, D-7, D-16, D-23, D-18)
City Planning	58, 60, 62, 64 (Discussion: D-16, D-23)
Construction	43, 50, 55, 71 (Discussion: D-3, D-8, D-23, D-17, D-40)
Engineering Economics	46, 47, 62, 64, 65, 68, 69 (Discussion: D-2, D-19, D-27, D-30)
Engineering Mechanics	41, 49, 51, 54, 56, 59, 61, 88, 89 (Discussion: D-5, D-XXIII, D-XXV, D-18, D-24, D-33, D-34)
Highway	43, 44, 48, 58, 70 (Discussion: D-XXVIII, D-7, D-16, D-23, D-13)
Hydraulics	50, 55, 56, 57, 70, 71, 78, 79, 80, 83, 86 (Discussion: D-XXVII, D-9, D-11, D-19, D-28, D-29)
Irrigation	46, 47, 48, 55, 56, 57, 67, 70, 71, 87, 88 (Discussion: D-XXIII, D-3, D-7, D-11, D-19, D-25-K, D-29, D-17, D-30, D-38, D-40)
Power	48, 55, 56, 69, 71, 88 (Discussion: D-XXIII, D-2, D-3, D-7, D-11, D-19, D-25-K, D-17, D-30, D-38, D-40)
Sanitary Engineering	55, 56, 87 (Discussion: D-10, D-29)
Soil Mechanics and Foundations	43, 44, 48 (Discussion: D-4, D-XXVIII, D-7)
Structural	42, 49, 51, 53, 54, 59, 61, 66, 89 (Discussion: D-5, D-3, D-8, D-16, D-23, D-13, D-21, D-24, D-25-K, D-32, D-17, D-33, D-34)
Surveying and Mapping	50, 52, 55, 60, 63, 65, 68
Waterways	41, 44, 45, 50, 56, 57, 70, 71 (Discussion: D-XXVII, D-9, D-8, D-19, D-27, D-28)

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DISCUSSION

CLEVES H. HOWELL,[2] M. ASCE.—This paper by Mr. Weiss describes unique and successful solutions of difficult diversion problems encountered in the construction of four embankment-type dams in Mexico. Flood waters were discharged successfully over the loose-rock, downstream slopes of three partly constructed dams by protecting those slopes by grids of reinforcing bars—and nothing else.

The downstream slope of the fourth dam (Valsequillo Dam near Puebla, in the State of Puebla) was covered with a reinforced concrete slab provided with weep holes. This design seems to have functioned in passing flood water almost as well but certainly no better than the previous ones which provided for reinforcing bar grids only. As suggested by Mr. Weiss, it seems quite reasonable that a grid of reinforcing bars only, as used on the other jobs, would have been quite as efficient and less expensive.

The engineers of Los Angeles (Calif.) County Flood Control District have had wide and instructive experiences with many types of bank and levee protection under high and low velocities in widely different kinds of channels. Several years prior to the great flood of March, 1938, portions of the banks of the San Gabriel and San Antonio Rivers at the mouths of the canyons, and some of the levees below, were protected by rock and wire mattresses. The mattresses were made by placing woven wire on the bank or levee slope, covering the wire with a layer of screened gravel (which, in turn, was covered by woven wire tied to the lower wire by previously placed ties).

During the great flood of March, 1938, this type of protection received a terrific beating, not only from the high velocity of the stream flow but also from the pounding of heavy boulders rolled along the river beds by the fast water. With very minor exceptions all of the installations stood firm. In connection with the facts given, however, it should be noted that, in general, the levees and banks were nearly parallel with the direction of the current. There were no direct head-on attacks.

Mr. Weiss and the other engineers of the Mexican Ministry of Hydraulic Resources, with characteristic clarity of thought and freedom from antique inhibitions, went a long step further. They deliberately discharged large volumes of water over, down, and at right angles to the steep downstream slopes of loose-rock embankments protected only by grids of reinforcing bars. They did this with success. Most engineers would have said it could not be done without disaster.

One is reminded of the numerous things that "could not be done," which were done by Captain James B. Eads, Fellow, ASCE, seven or eight decades ago. "Time marches on."

NOTE.—This paper by Andrew Weiss was published in October, 1950, as *Proceedings-Separate No. 40*. The numbering of footnotes in this Separate is a continuation of the consecutive numbering used in the original paper.

[2] Longmont, Colo.

GERARD H. MATTHES,[3] HON. M. ASCE.—Necessity may be the mother of invention, but it takes courage to proceed contrary to long established principles. It has been standard practice in the United States never to permit water to flow over an earth embankment either during construction or after completion. This dogma dates back largely to the Johnstown (Pa.) flood (1889) that was caused by high water overtopping an unprotected earth dam. It is refreshing to learn that our neighbors in Mexico have found a way to scrap this time-honored inhibition. Erratic rainfall and runoff conditions coupled with enigmatic subsurface conditions (one never knows in Mexico what troubles may lurk in the space between any two borings) aptly describe the Mexican engineer's routine problems.

The writer was fortunate in visiting several dams with the author, among them the 269-ft earth and rock-fill Valsequillo Dam that had been overtopped by floods three successive times during construction. At the time of this visit the structure had stood completed for more than a year with water close to spillway level. Inspection revealed no leakage at the toe. The limestone conglomerate foundation rock that also composes the walls of the 100-ft deep chasm showed major cracks running in several directions and caused by volcanic disturbance. The sealing of these cracks by grouting, more especially in the vertical chasm walls, had been a chief concern, and to the writer it seemed an almost incredible accomplishment. Aside from this feature of the job the problem of protecting the earth fill against erosion by overtopping had been no new problem to the author as his previous experience with passing floods over earth fills at other dam sites had already pointed the way. In this instance, a concrete slab as described was used to prevent the mesh of reinforcing bars from being demolished by trees and stumps. Inspection of the concrete slab and the manner in which it had been lifted by the force of water for lack of weep hole capacity impressed the writer with its limitations. He felt that no slab but a more secure anchorage for the reinforcing bars would have been a more satisfactory solution in this particular case as there was no scarcity of large rock which could have been held in place by the mesh of bars alone.

Reviewing the experience gained at the various dams described, the important points to be observed in protecting earth dams with rock fills against damage by overflow during construction may be set down as follows:

(*a*) The top of the earth fill should be maintained as flat as practicable, with a light upward grade in a downstream direction. This calls for methodical placing, spreading, and rolling of the materials without interfering with common procedure in these respects except for maintaining the top surface at all times on a slope.

(*b*) Grading of the rock fills (filter fashion) from finest material next to the impervious fill to coarse material at the face requires more than ordinary care in order that no loss of impervious fill material shall occur during periods of overflow.

(*c*) Of prime importance is the necessity of keeping the downstream rock fill at a height well above the level of the earth fill at all times in readiness for a

[3] Cons. Hydr. Engr., New York, N. Y.

sudden flood. This provision applies likewise to the top of the concrete slab in case one is used.

(*d*) Where rocks of sufficiently large sizes are procurable in quantity capable of resisting entrainment by flood flow, no concrete slab is needed.

(*e*) To hold the larger rock-fill material in place, a grillage or mesh of steel bars is required, with meshes to be adequate for preventing any of the larger rock from passing through. The mesh must be held at suitable intervals by means of steel rods fastened to steel disks buried to some depth in the river bed.

(*f*) The crest of the downstream rock fill must be held in place so securely that by no chance can any part of it be eroded during overtopping.

(*g*) Where rocks of large enough sizes are not procurable for the outer face of the upstream rock fill, a concrete slab, provided with a plurality of weep holes, can be substituted. The slab should be reinforced with steel bars tied back by steel rods running to anchors.

(*h*) Customary methods of inspection on earth fill dam construction must be discarded in favor of constant close inspection by engineers qualified to deal promptly with high-water emergencies and capable of making on-the-spot decisions regarding suitability of materials, steel mesh anchorages, proper grading of rock fills, and the like.

(*i*) Ordinary and low river discharges are best handled through a small by-pass tunnel; only flow in excess of by-pass capacity is then permitted to pass over the uncompleted structure.

(*j*) After completion the dam is no longer subject to overtopping by floods, ample spillway capacity being provided.

The writer takes this opportunity to call attention to the use of concrete tetrahedral blocks as admirably suitable instead of large rock at the downstream face. The use that was made of such blocks in building the cofferdam for the Genissiat hydro development on the Rhone River [4,5,6] is recalled. There a row of very large tetrahedrons was placed in the flowing river, each block being held in place by a cable fastened to an anchor at an upstream point. Smaller tetrahedrons were then placed by dumping behind this first row together with rock large enough to lodge firmly. A loose fill of assorted materials followed, and the downstream face of the cofferdam then was carried to higher elevations by means of additional rows of tetrahedrons similarly held in place by anchorages. Earth fill finally made this cofferdam water tight. This method with suitable changes would be well adapted to the Mexican system described.

There appears to be no reason why the construction technique employed in Mexico should not find application in the United States. Superior hydrologic information concerning maximum rates of runoff has naturally led American engineers to by-pass flood flow through costly tunnels or open channels during construction. The experience gained in Mexico with passing flood waters over uncompleted earth structures indicates that flood flow can be made to pass over compacted earth fills without appreciable loss of materials provided the protection at upstream and downstream faces is made adequate. Material savings

[4] "Barrages en Pierres Lancées," by Charles Blanchet, *La Houille Blanche*, No. 2, 1946, p. 141.
[5] *Ibid.*, No. 4, 1946, p. 393.
[6] *Ibid.*, No. 1, 1947, p. 41.

in cost and time of construction can thus be realized by dispensing with large by-passes.

The author is to be commended for his very frank and unvarnished account of the successes and partial failures experienced in developing this relatively new method of building earth dams. He has blazed a new trail that will be worth following.

ANDREW WEISS,[7] HON. M. ASCE.—The protective works built by the Los Angeles (Calif.) County Flood Control District, described by Mr. Howell, were distinctly successful. The principle that made them such an outstanding success was essentially the same as that applied in the use of a protective grid of reinforcing bars where larger rock is available. The District used a heavy wire mesh to retain the mass of screened gravel, the latter being of sufficient coarseness to be retained by the wire mesh, thus supplying the required weight anchorage and resistance against the transporting forces of the river current. It is a method of protecting riverbanks which is applicable to a much greater extent than in present practice, considering the large number of places where rock of the proper quality and size is too costly for the purpose.

A similar system of protection is in use on the San Lorenzo River in Sinaloa, Mex., where rock "sausages" are made of screened gravel wrapped in a strong wire mesh. However, the "sausages" available for inspection were past their usefulness; the wire meshes were broken, showing the rough treatment to which they had been exposed in a river subject to heavy floods and high velocities.

A similar method of river control involving the use of "gaviones," has been developed in a modified form as river training works in Bolivia. At locations where conditions make the use of these devices economical and practical, this is a logical procedure. It seems that the same system has been adopted, with much greater refinement, in Italy where some construction companies use wire mesh baskets filled with screened gravel which are placed in imitation of dry stone masonry. It seems doubtful that such uses could be applied economically in Mexico, especially when the method is to be used as a construction technique and in no case as a part of the finished design. It is never suggested that wire mesh units (which are often as expensive to build as the storage works themselves) shall be incorporated as an integral part of the permanent spillway structure.

On his visit to several of the dams and dam sites in Mexico, Mr. Matthes had a good suggestion to offer, and he described a precaution to be applied in using this technique on the standard type, rolled earth fills such as the Valsequillo Dam. It is really suprising how simple is the problem of sorting and grading the transition zone, thus defeating any tendency of parts of the dam to become eroded during construction. No special screening of materials is needed. Anyone employed in building dams in climates and conditions prevalent in certain parts of Mexico and in building similar types of dams elsewhere is very likely to encounter such conditions. It is not so common to find such climatic conditions in the United States. It is certain that no one should go out of his way to seek such opportunities of doing extra work and spending funds unless

[7] Cons. Engr., National Comm. of Irrig., Mexico, D. F., Mexico.

the conditions warrant such precautions; but the engineer is quite likely to find them sooner than he expects, and he should be prepared to meet them as well as is possible.

The use of tetrahedrons for anchoring such a rock fill appears attractive where prevailing conditions make this method preferable. It might be less attractive in places like Mexico on account of the greater scarcity of the materials needed and the lack of suitable roads. Doubtless the contractor or his client would be obliged to take these conditions into account and use their own good judgment before selecting tetrahedrons.

The partial failure that the administration encountered on the El Azúcar (Marte Gómez) Dam was doubtless due to the insufficient height of the slope protection which permitted the flood waters to invade an unprotected bordering terrace deposit; but even after an overflow period of about 3 days, the damage was unimportant in comparison with the resulting economies secured. This experience emphasizes the need of confining such measures so that resulting damages may be kept within the extent of destruction that would result from natural floods in the same valley. Reliable agencies have recorded a number of such natural floods; and similar records are generally available in regions where irrigation is a known practice or where some reliable gaging station has been established, such as that of the International Boundary Commission, 6 miles upstream from the El Azúcar Dam.

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